

## **Medical applications of the South African National Accelerator Center – Radioisotope Production and Particle Beam Therapy**

**Basis of facility is 200 MeV open-sector cyclotron with two injector cyclotrons for light and heavy ions respectively**

- 1. A multidisciplinary facility serving three different disciplines:**

**Radioisotope production for nuclear medicine and other applications, e.g. agriculture, industry**

**Particle beam radiotherapy – protons and neutrons**

**Basic and applied research: Nuclear physics and nuclear chemistry**

- 2. General layout of accelerators and facilities**
- 3. Beam-time division for different facilities**
- 4. List of medical radioisotopes delivered to nuclear medical centers in South Africa and Namibia**

**5. Target handling and bombarding facilities**

**6. Thermal analysis of solid targets**

**7. Gas targets**

**8. Research and development**

**Chemical synthesis of organic precursors suitable for labeling, and their purification**

**Ion exchange behaviour of elements for planning separations and estimating optimum conditions in chromatography**

**Development of new sources e.g. Se-75, determining excitation functions**

**Exotic projects e.g. cannabis labeling to determine distribution of cannabis receptors in the human brain**

## **Advantages of RIA w.r.t. standard methods**

**Enormous choice of half-lives, decay types (also longer decay chains), and energies**

**New types of radiation e.g. medium mass  $\alpha$ -emitters**

**The combinations of energies and intensities available will allow control of the depth, intensity and location of implantation**

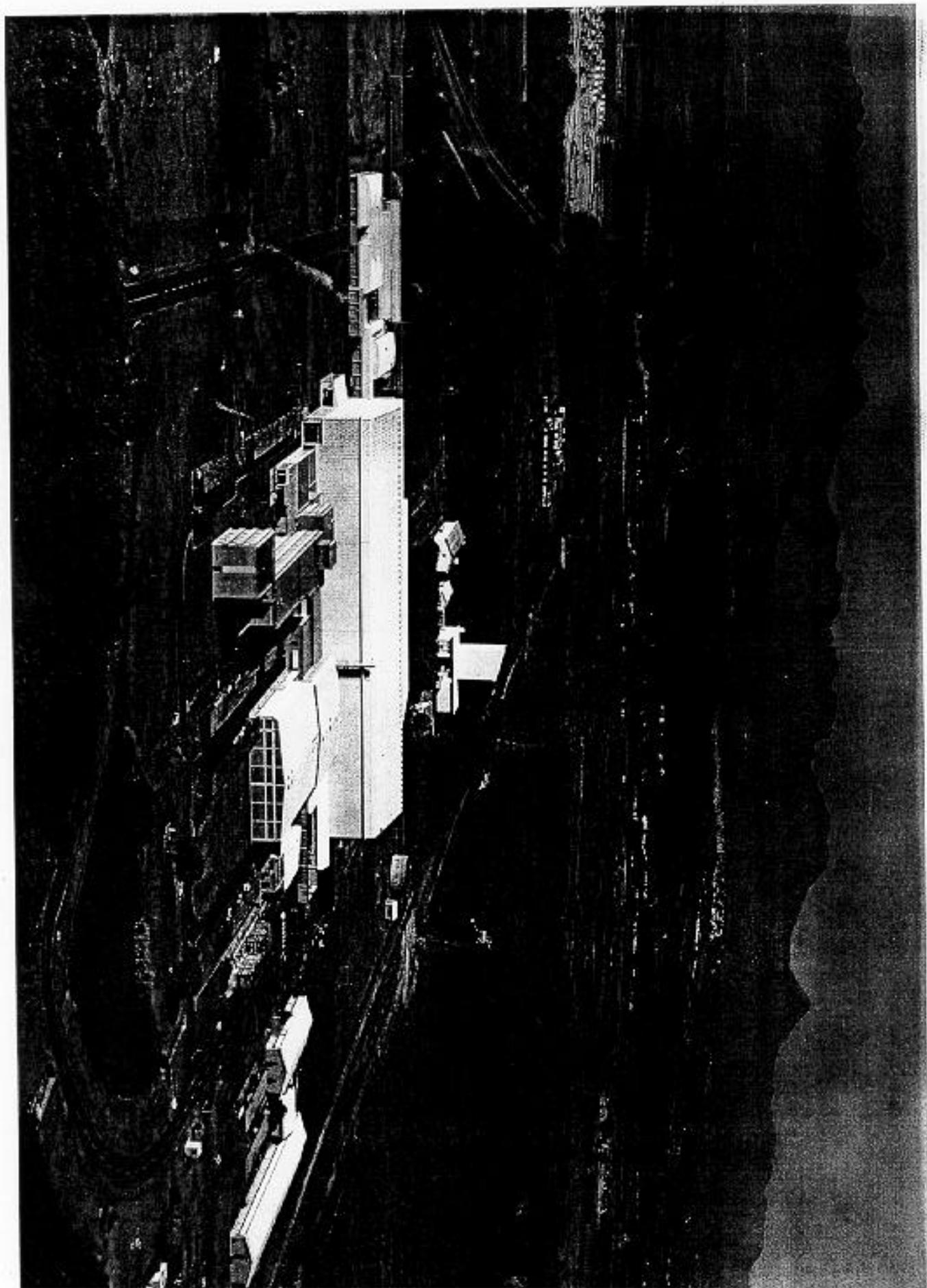
**Low-energy beams of precisely variable energy**

**Implantation introduces time-dependent chemical changes into a biological system**

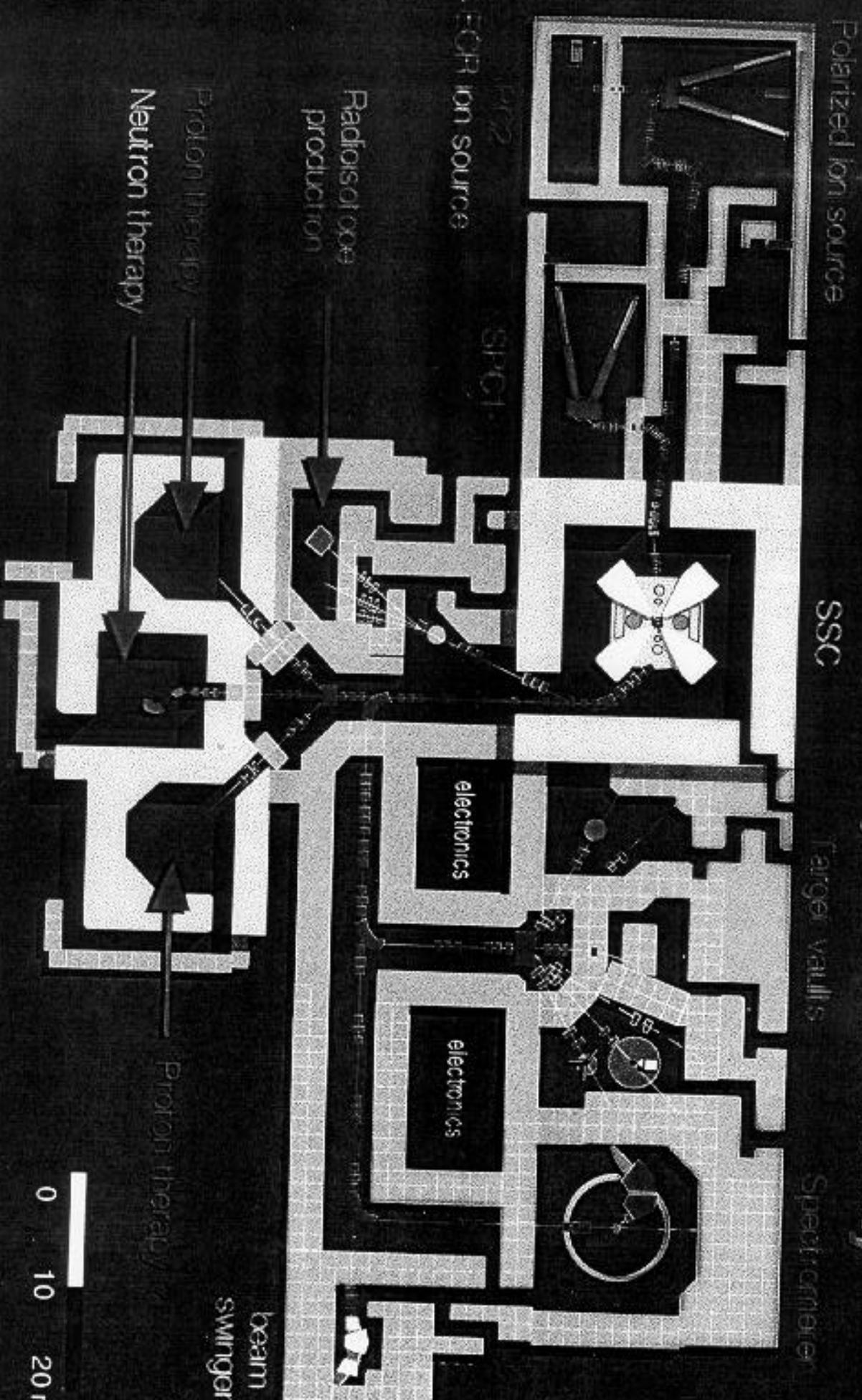
**Higher isotopic purity (carrier-free) radioisotopes in beams to be used**

**Greater variety of such isotopically pure beams will enable selection of best possible isotope for a particular application**

**Exotic applications e.g. radioactive atom trapped in buckyball**



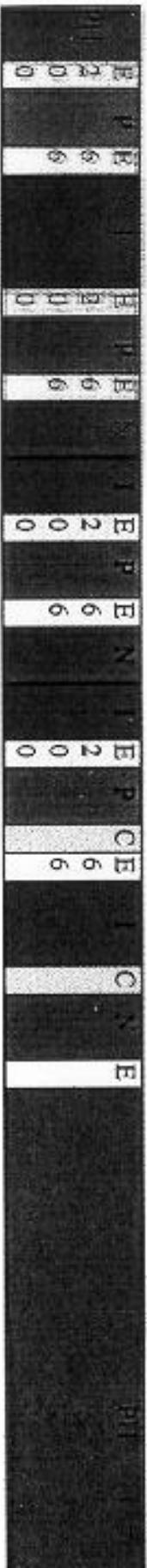
# Separated-Sector Cyclotron Facility



# NEW AND PREVIOUS OPERATING SCHEDULES FOR THE NAC CYCLOTRONS

Monday	Tuesday	Wednesday	Thursday	Friday	Saturday	Sunday
--------	---------	-----------	----------	--------	----------	--------

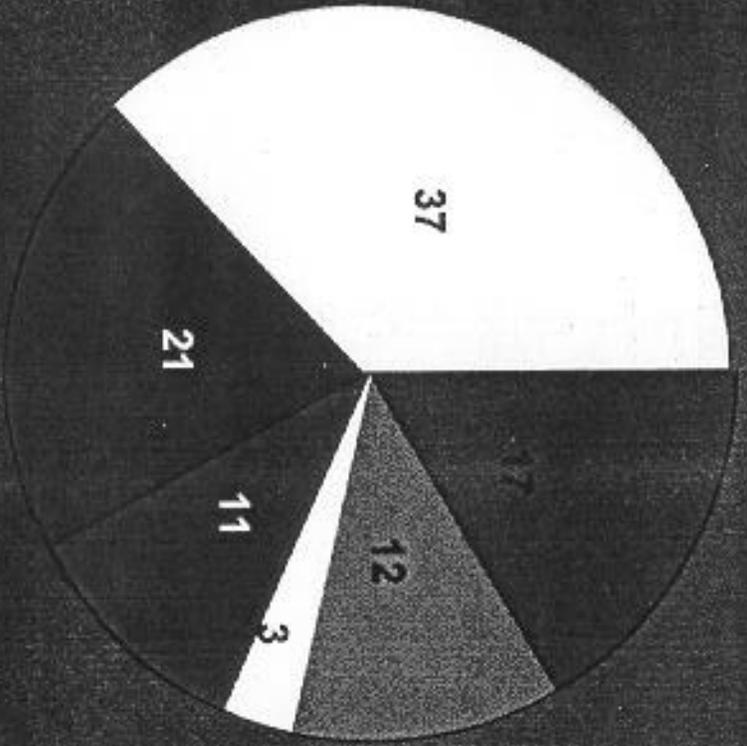
3 6 9 12 15 18 21 24 | 3 6 9 12 15 18 21 24 | 3 6 9 12 15 18 21 24 | 3 6 9 12 15 18 21 24 | 3 6 9 12 15 18 21 24 | 3 6 9 12 15 18 21 24 | 3 6 9 12 15 18 21 24



Monday	Tuesday	Wednesday	Thursday	Friday	Saturday	Sunday
--------	---------	-----------	----------	--------	----------	--------



- PH Nuclear Physics
- E Energy Change
- N Neutron Therapy
  
- P Proton Therapy
- I Production of Radioisotopes
- C Calibration time



- Proton Therapy
- Neutron Therapy
- Therapy Calibrations
- Energy Change
- Isotope Production
- Nuclear Physics

RADIONUCLIDE	PRODUCTION ROUTE	
	NAC	COMMON
$^{18}\text{F}$	$\text{Ne}(p, X)^{18}\text{F}$	$^{18}\text{O}(p, n)^{18}\text{F}$ $^{20}\text{Ne}(d, \alpha)^{18}\text{F}$
$^{67}\text{Ga}$	$\text{Zn}(p, xn)^{67}\text{Ga}$ $\text{Ge}(p, X)^{67}\text{Ga}$	$^{68}\text{Zn}(p, 2n)^{67}\text{Ga}$
$^{68}\text{Ge}$	$\text{Ga}(p, xn)^{68}\text{Ge}$	$\text{Ga}(p, xn)^{68}\text{Ge}$
$^{81}\text{Rb}/^{81m}\text{Kr}$	$\text{Kr}(p, xn)^{81}\text{Rb}$	$^{82}\text{Kr}(p, 2n)^{81}\text{Rb}$
$^{82}\text{Sr}$	$\text{Rb}(p, xn)^{82}\text{Sr}$	$\text{Rb}(p, xn)^{82}\text{Sr}$
$^{111}\text{In}$	$\text{In}(p, xn)^{111}\text{Sn} \rightarrow ^{111}\text{In}$	$^{112}\text{Cd}(p, 2n)^{111}\text{In}$ $^{109}\text{Ag}(\alpha, 2n)^{111}\text{In}$
$^{123}\text{I}$	$^{127}\text{I}(p, 5n)^{123}\text{Xe} \rightarrow ^{123}\text{I}$	$^{124}\text{Xe}(p, X)^{123}\text{I}$
$^{201}\text{Tl}$	$^{203}\text{Tl}(p, 3n)^{201}\text{Pb} \rightarrow ^{201}\text{Tl}$	$^{203}\text{Tl}(p, 3n)^{201}\text{Pb} \rightarrow ^{201}\text{Tl}$

# Radioisotope production

- **Dedicated production 4 nights per week plus time between patients**
- **NAC satisfies local demand for accelerator-produced short-lived medical radioisotopes and radiopharmaceutical products**
- **NAC routinely supplies**
  - **more than 1000 consignments**
  - **to more than 30 hospitals, etc.,**
  - **for nearly 10 000 patients per year**
- **Long-lived radioisotopes (for export) with spare beam**
- **PET capability**

# Radioisotope production

## Main activities

- **Routine supply** of diagnostic radiopharmaceuticals to local hospitals and private clinics:

$^{67}\text{Ga}$ ,  $^{123}\text{I}$  and  $^{123}\text{I}$ -compounds,  $^{81}\text{Rb}/^{81\text{m}}\text{Kr}$ -generators,  $^{18}\text{F}$ [FDG],  $^{111}\text{In}$ ,  $^{201}\text{Tl}$

- **Research and development**

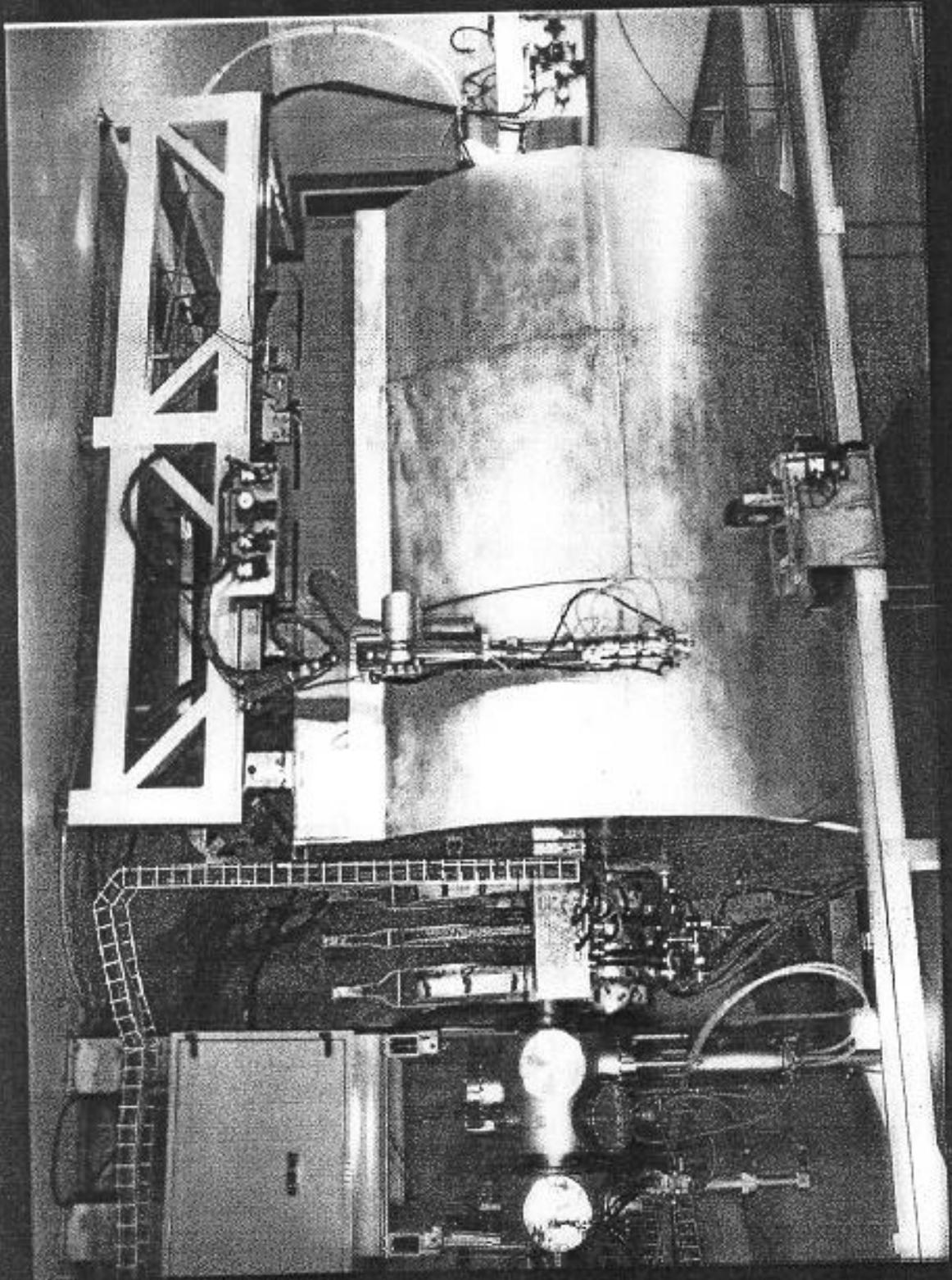
- **Physics** (nuclear data and high-current targetry, radioactivity standardization)
- **Chemistry** (chemical separation procedures)
- **Radiopharmaceutical chemistry** (labeled compounds such as  $^{123}\text{I}$ -compounds,  $^{18}\text{F}$ [FDG], etc.)

# Radioisotope production

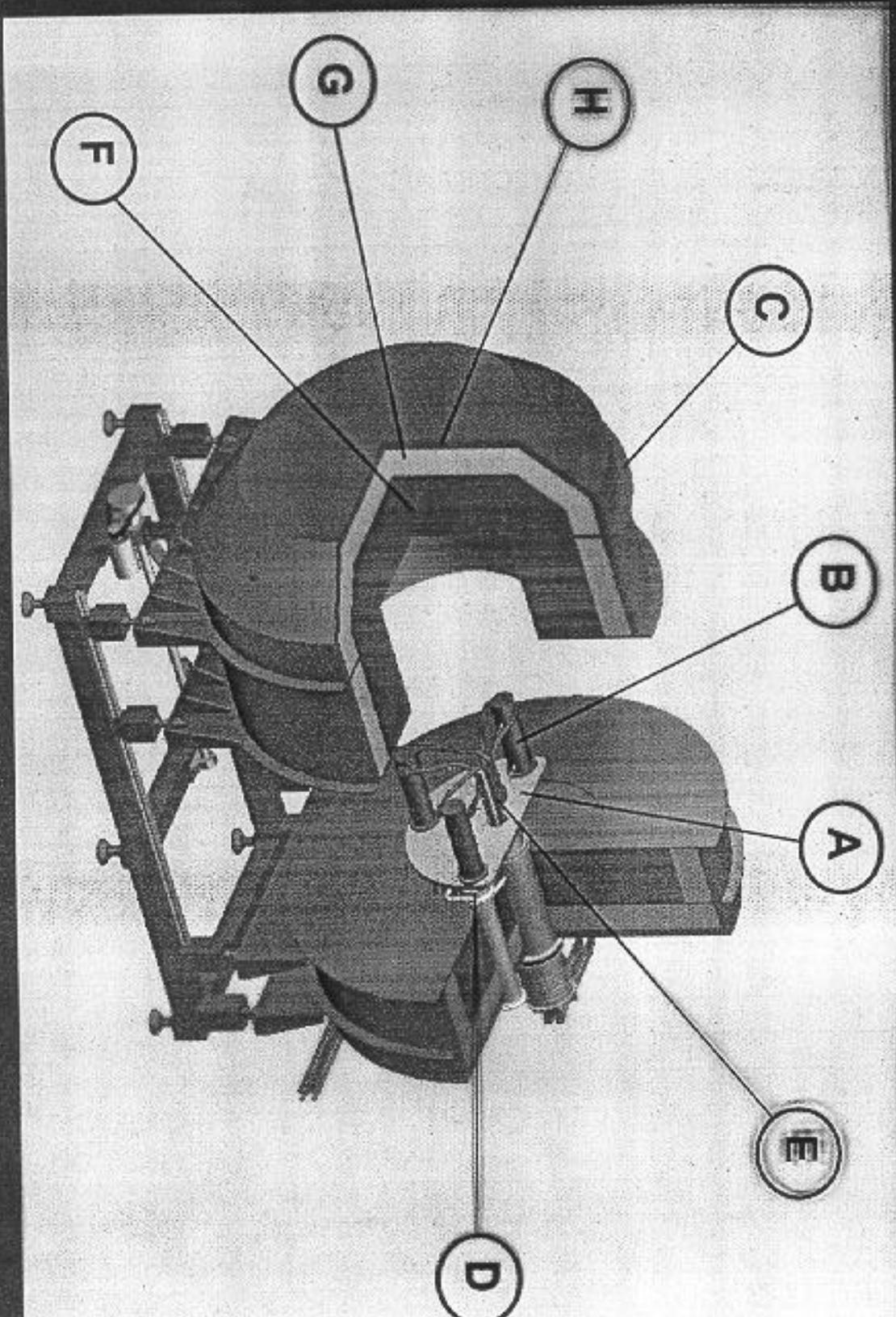
## Main activities

- **Production and marketing of longer-lived radioisotopes for export:**  
 $^{22}\text{Na}$ ,  $^{55}\text{Fe}$ ,  $^{68}\text{Ge}$ ,  $^{82}\text{Sr}$ ,  $^{103}\text{Pd}$  and  $^{139}\text{Ce}$
- **Training** in chemistry and physics  
In-service training, B-Tech, M-Tech, M.Sc, PhD

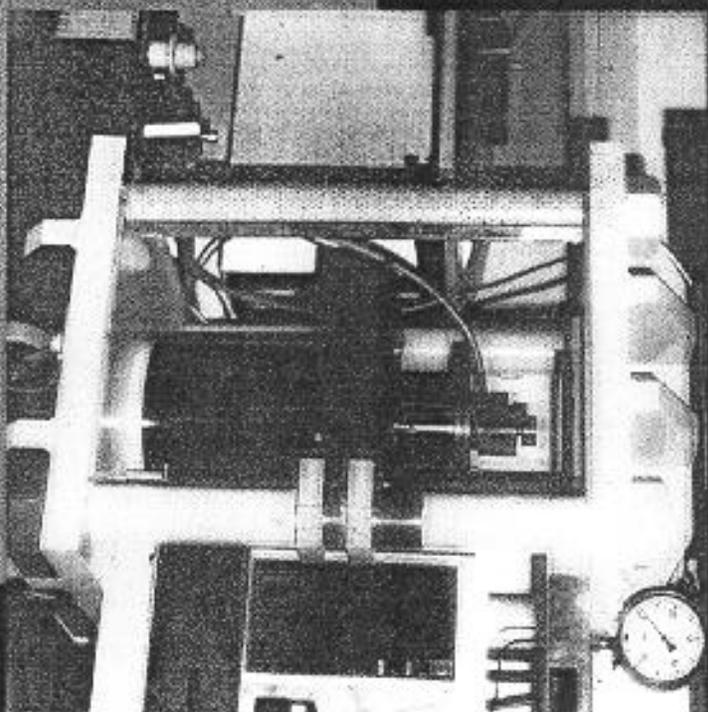
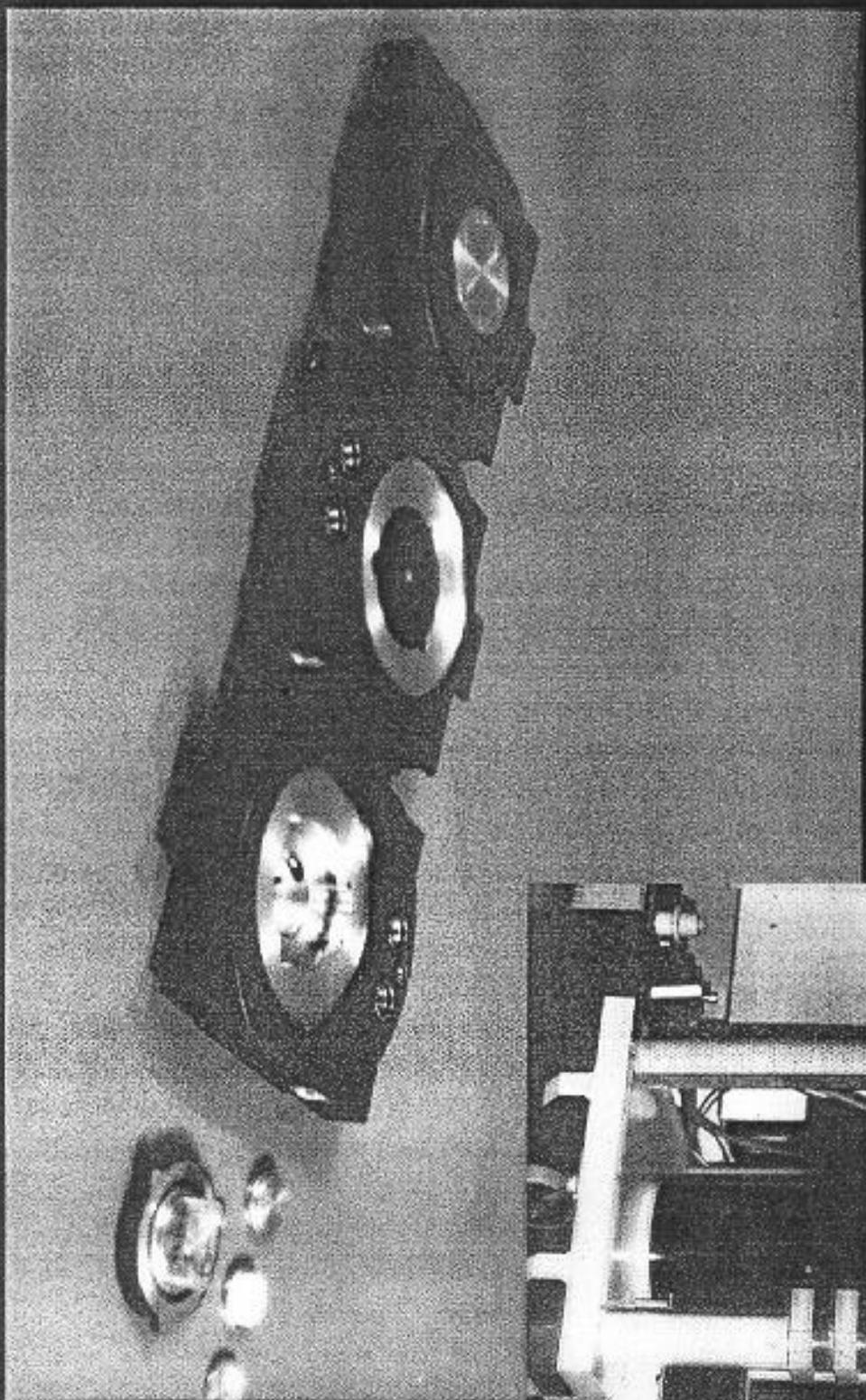
# Bombardment station 1



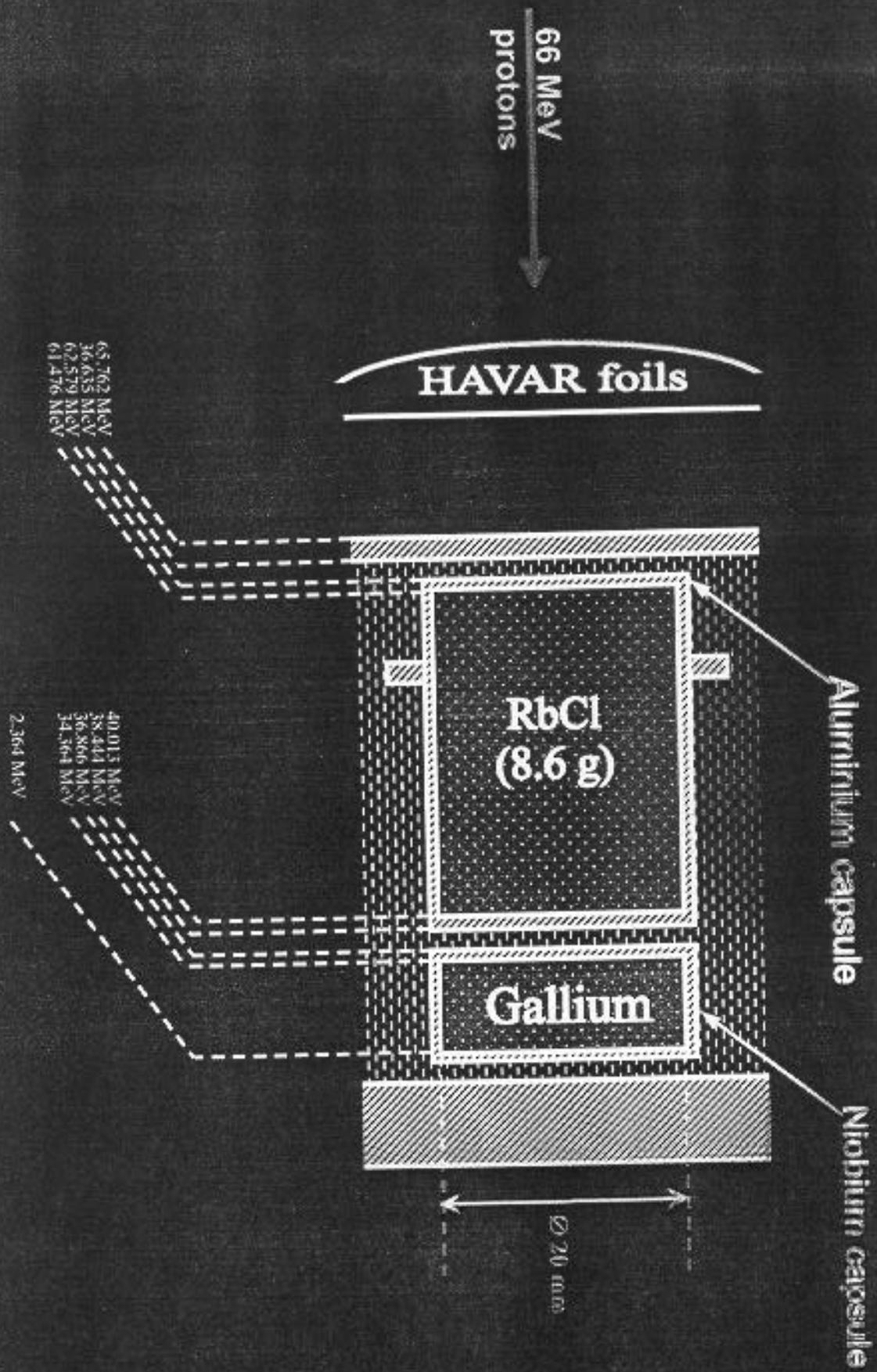
Second shielded target station



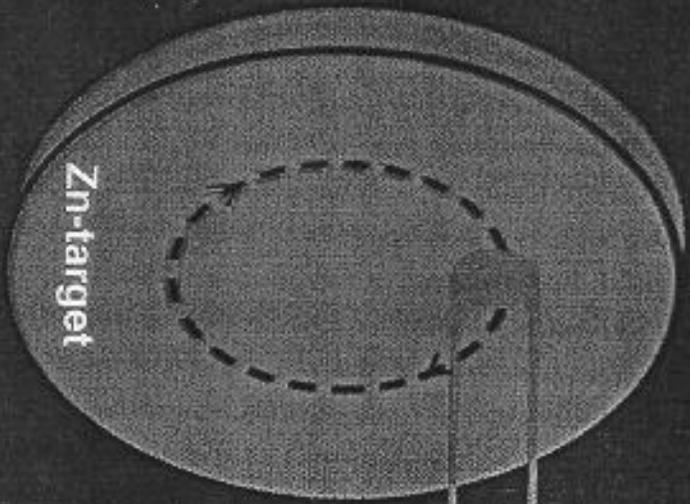
## Solid targets



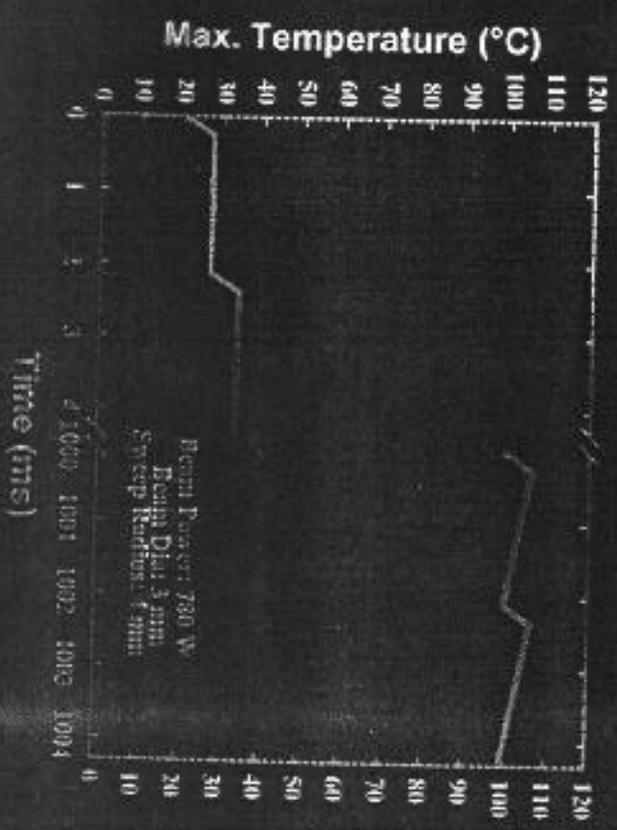
# Tandem target for the production of $^{82}\text{Sr}$ and $^{68}\text{Ge}$



# Circular Beam Sweeping



66 MeV protons



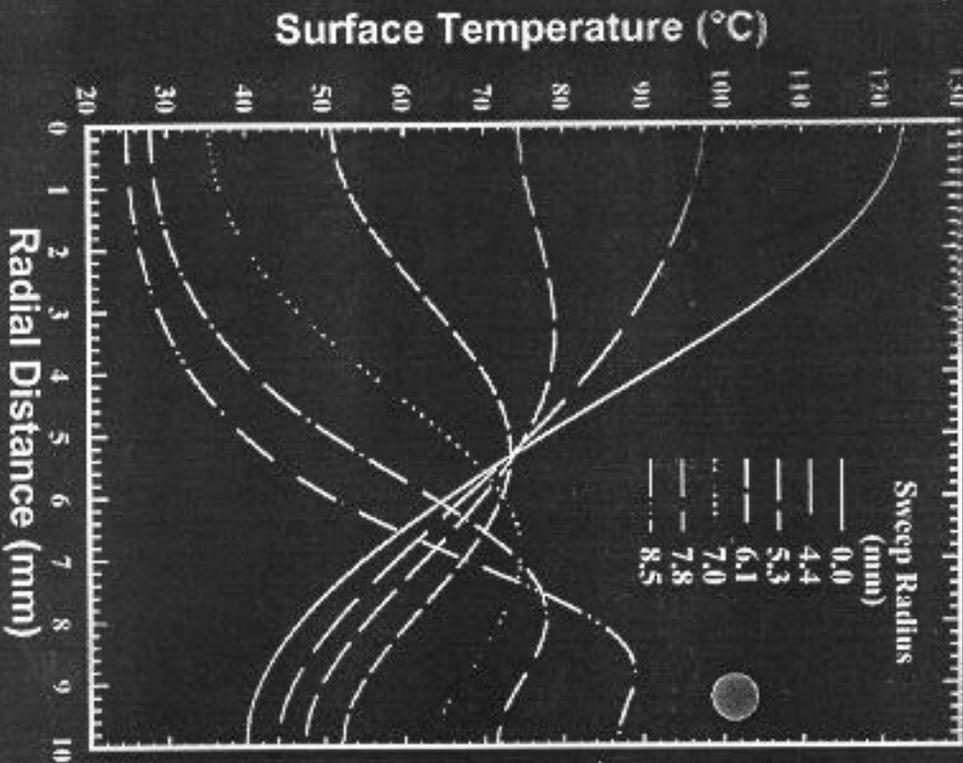
# Circular Beam Sweeping

## Temperature Distributions

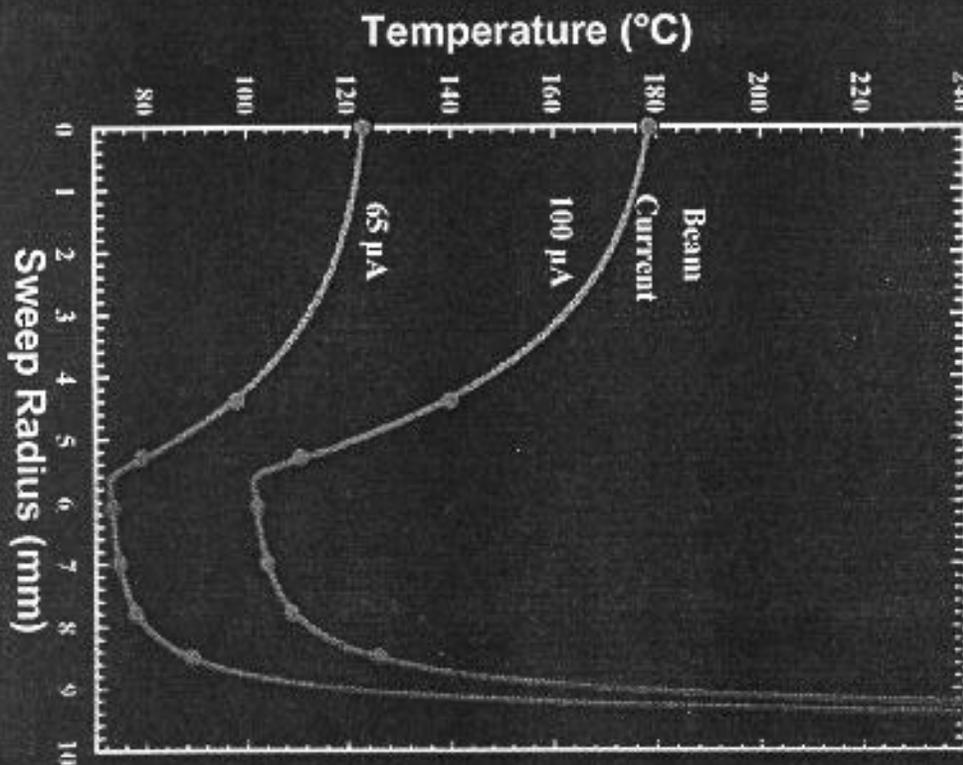
Energy Window = 37.5-18 MeV

Beam Current = 65  $\mu\text{A}$

Water Flow = 10 L/min per channel



## Peak Surface Temperatures



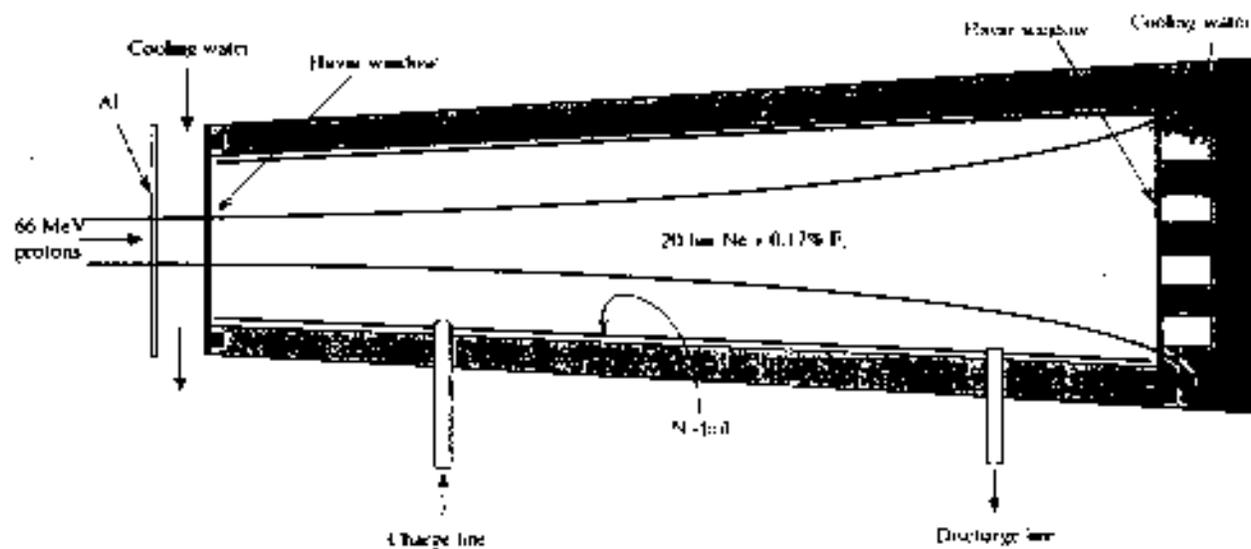
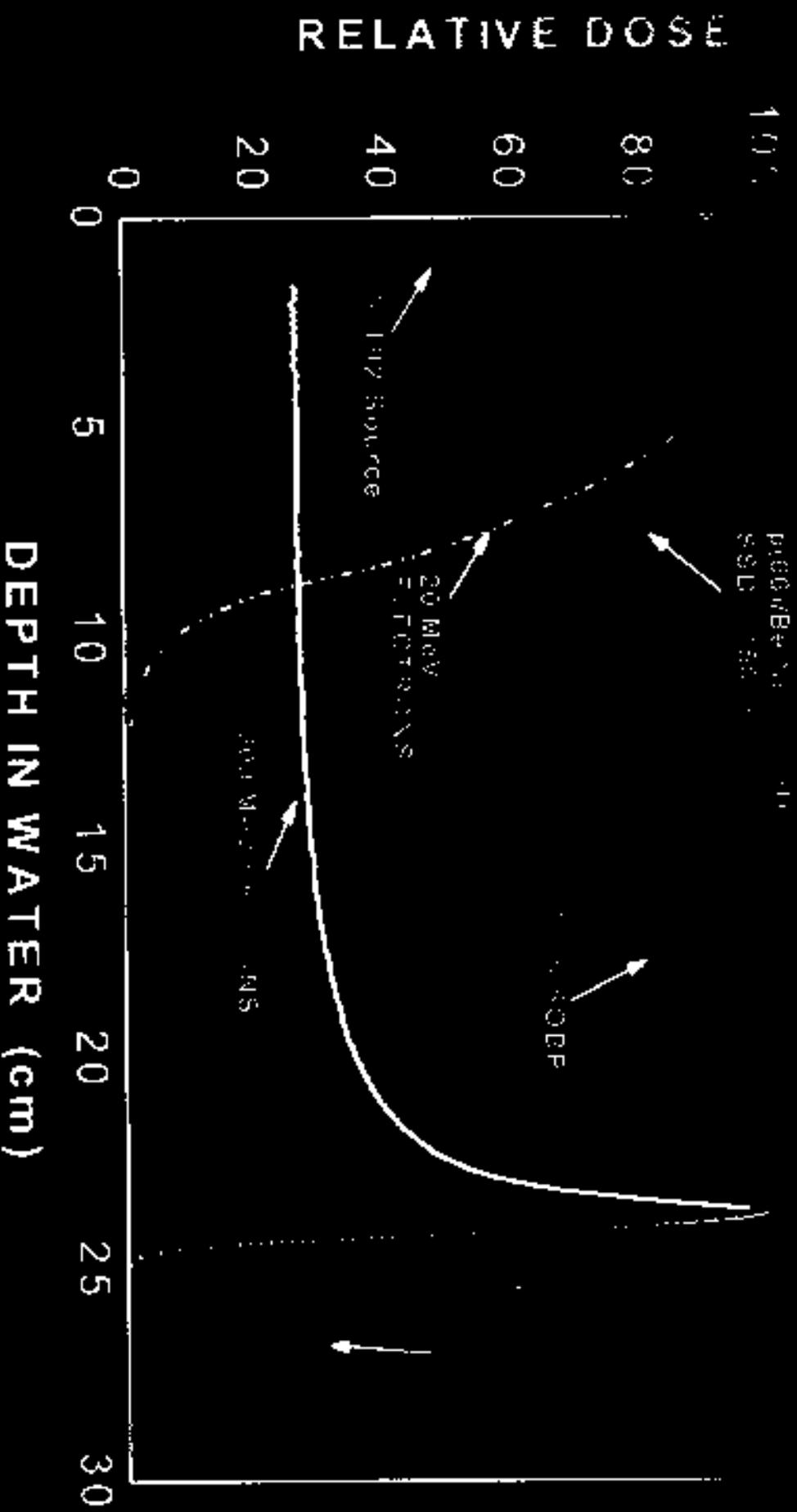
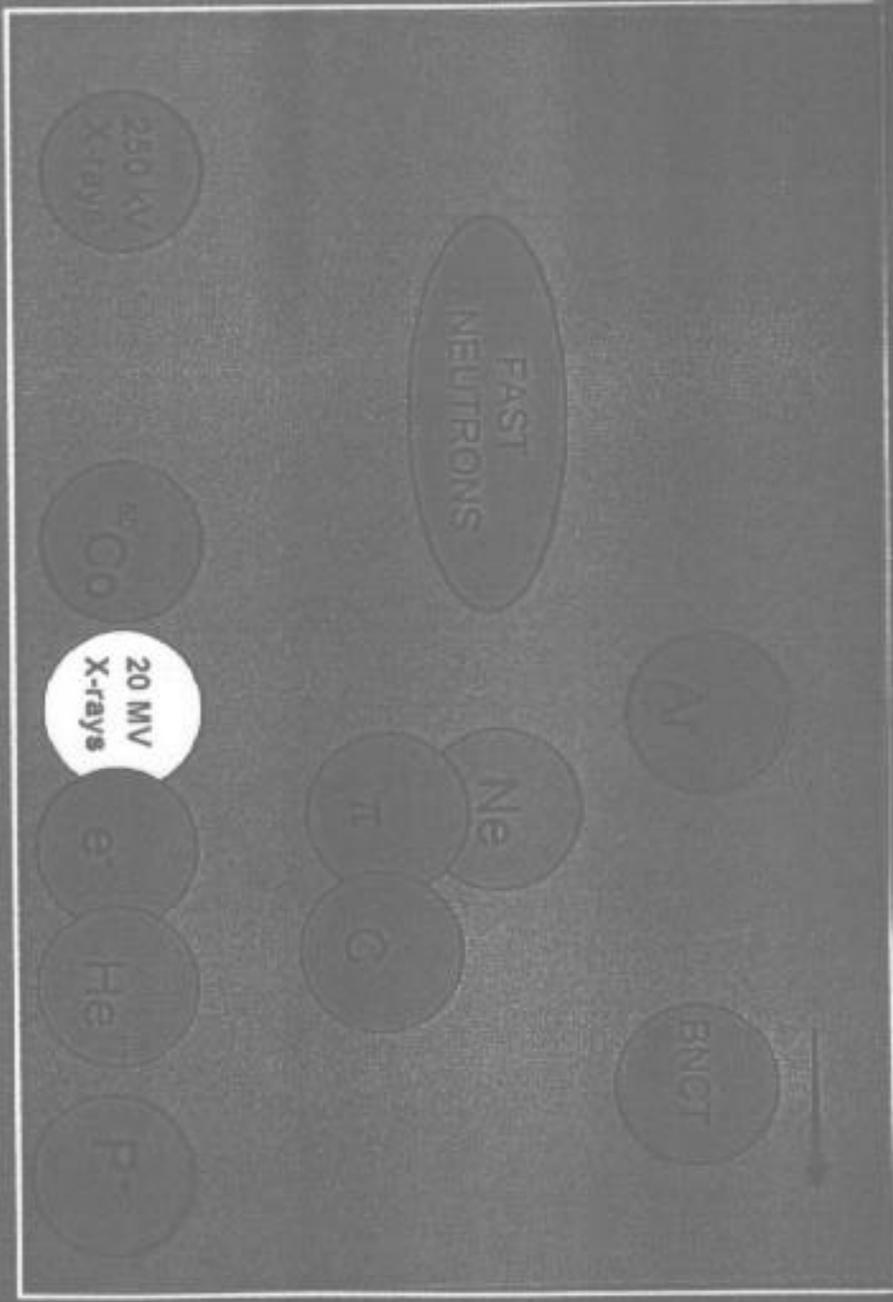


Fig. 11.1 Diagram of Ne gas target for the production of <sup>22</sup>F

RELATIVE DOSE vs. DEPTH IN WATER



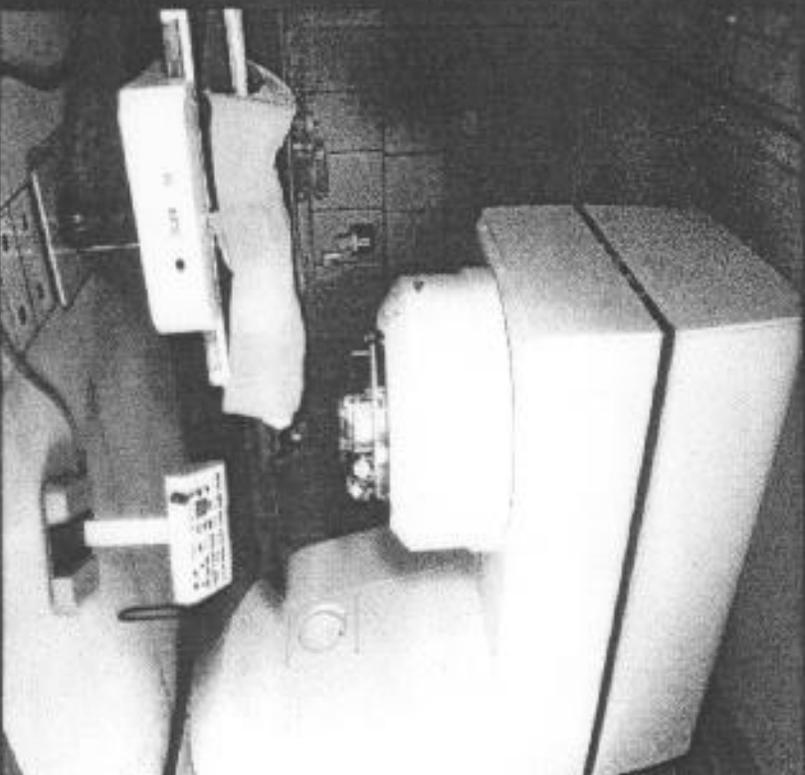
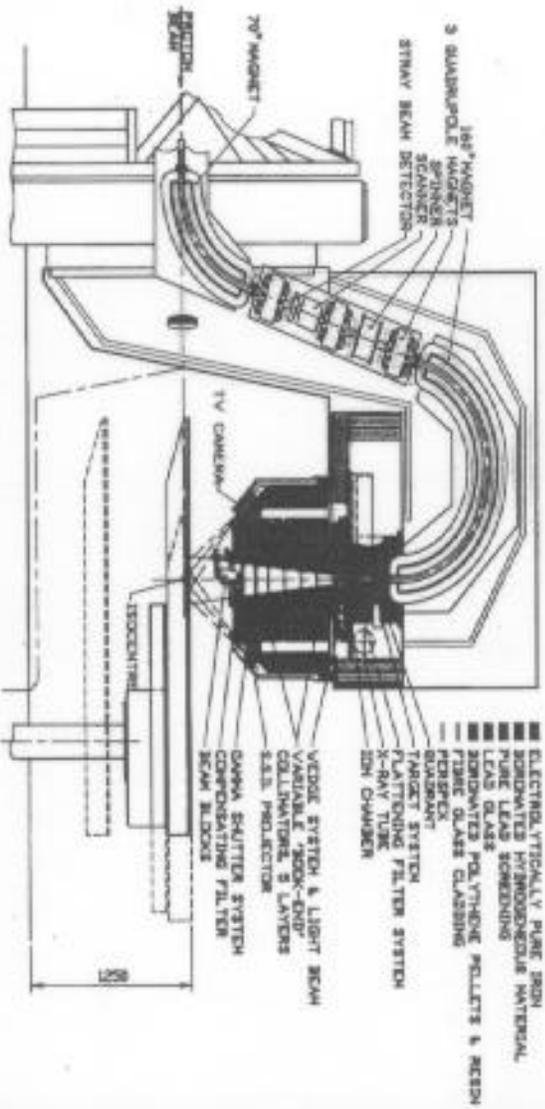
BIOLOGICAL ADVANTAGE →



DOSE DISTRIBUTION ADVANTAGE →

Physical selectivity

# The neutron isocentric treatment facility



# SPC System

CCD Cameras

Proton Beam Line

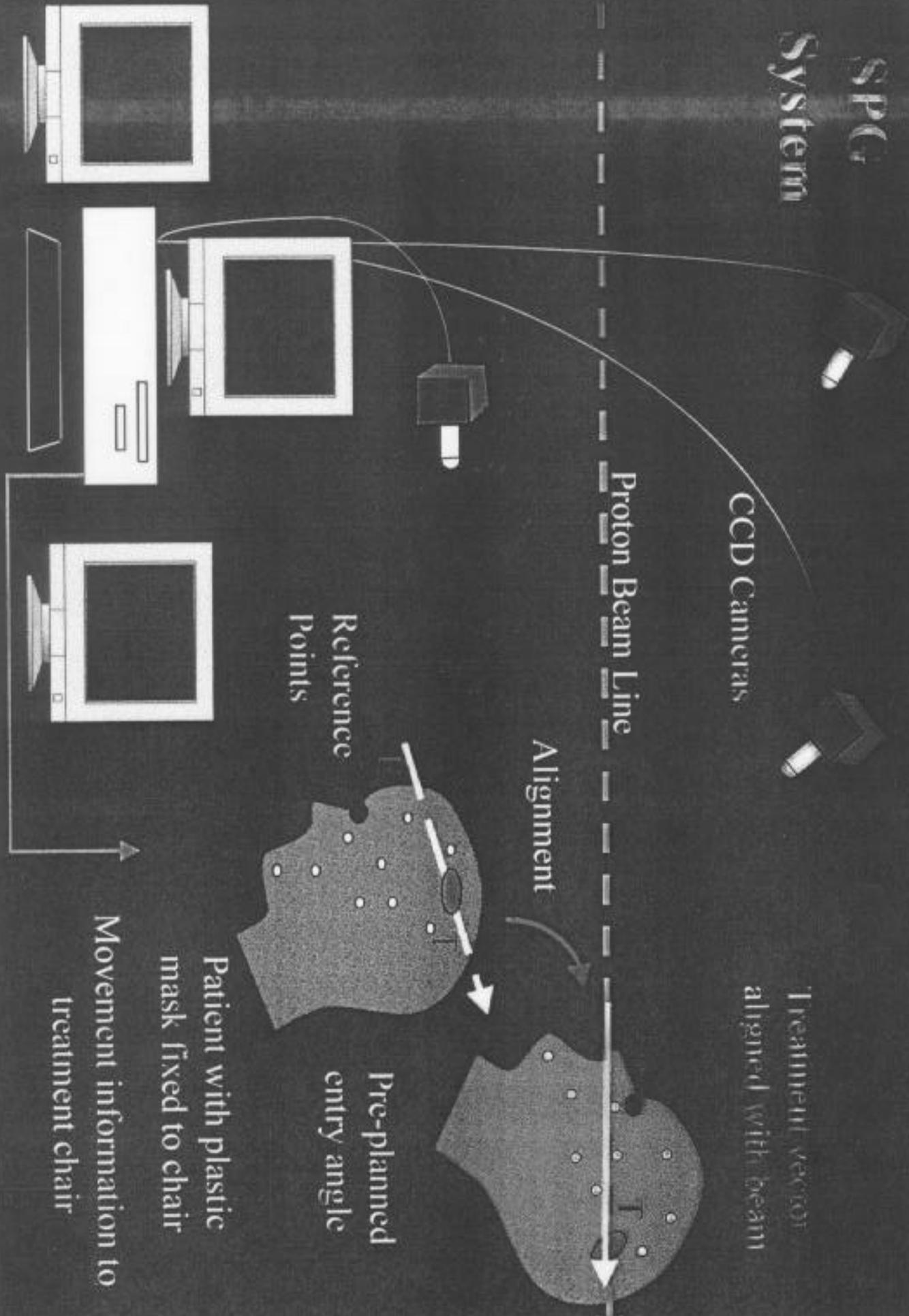
Alignment

Treatment vector  
aligned with beam

Reference  
Points

Pre-planned  
entry angle

Patient with plastic  
mask fixed to chair  
Movement information to  
treatment chair



**NAC NEUTRON THERAPY PATIENTS  
(6 SEP 1988 – 31 AUGUST 2000)**

DIAGNOSIS	NUMBER OF PATIENTS	
	TRIAL	NON-TRIAL
Head and neck carcinoma*	154 <sup>+</sup>	84
Salivary gland carcinoma	350	
Soft tissue sarcoma	94	
Breast carcinoma	101 <sup>+</sup>	16
Uterine cervix carcinoma <sup>o</sup>	5	
Bronchus carcinoma <sup>o</sup>	6	
Uterine sarcoma	65	
<b>Mesothelioma*</b>	21	
Paranasal sinus carcinoma	40	
Bone sarcoma	100	
Malignant melanoma	53	
Sundry		48
	<b>989</b>	<b>148</b>
	<b>1137</b>	

<sup>+</sup> Includes 60 patients in photon arms

<sup>o</sup> Trial discontinued

\* Trial suspended for evaluation

**PROTON THERAPY PATIENTS  
(10 SEP 1993 – 31 AUGUST 2000)**

<b>DIAGNOSIS</b>	<b>NUMBER OF PATIENTS</b>
Arteriovenous malformation	71
Acoustic neuroma	44
Pituitary adenoma	44
Meningioma	33
Brain tumour	48
Metastasis	26
Paranasal sinus	20
Skull base tumour	18
Orbit and eye tumour	20
Craniopharyngioma	10
Head and neck tumour	9
Prostate tumour	4
Other	26
	373